

# SAFETY VALVE TESTING AT ARE HASLAR

BY

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## ABSTRACT

Full flow testing of steam and water relief valves are carried out at Haslar. The three test stations in the facility operate with low pressure steam, high pressure high temperature steam, and high pressure high temperature water respectively.

## Introduction

The Naval Auxiliary Machinery Division (NAMD) of the Admiralty Research Establishment at Haslar in Hampshire has been in existence since 1902. Formerly called the Admiralty Fuel Experimental Station (AFES), its purpose was to conduct experiments into combustion in naval boilers with particular regard to the design of combustion equipment—burners, registers etc. Because boilers were used for trials work, steam was produced, and over the years this by-product was utilized to test steam auxiliary machinery.

From a small beginning NAMD grew, and the auxiliary machinery testing expanded and encompassed a whole range of equipment. Air conditioning plant, pumps, compressors, heat exchangers, filters, coalescers, waste disposal and desalination are some of the present trials areas, and there is a growing interest in machinery health monitoring and instrumentation. Thus it is against a background of large test houses, with supporting machine, plate, electrical and instrumentation workshops that testing is now conducted.

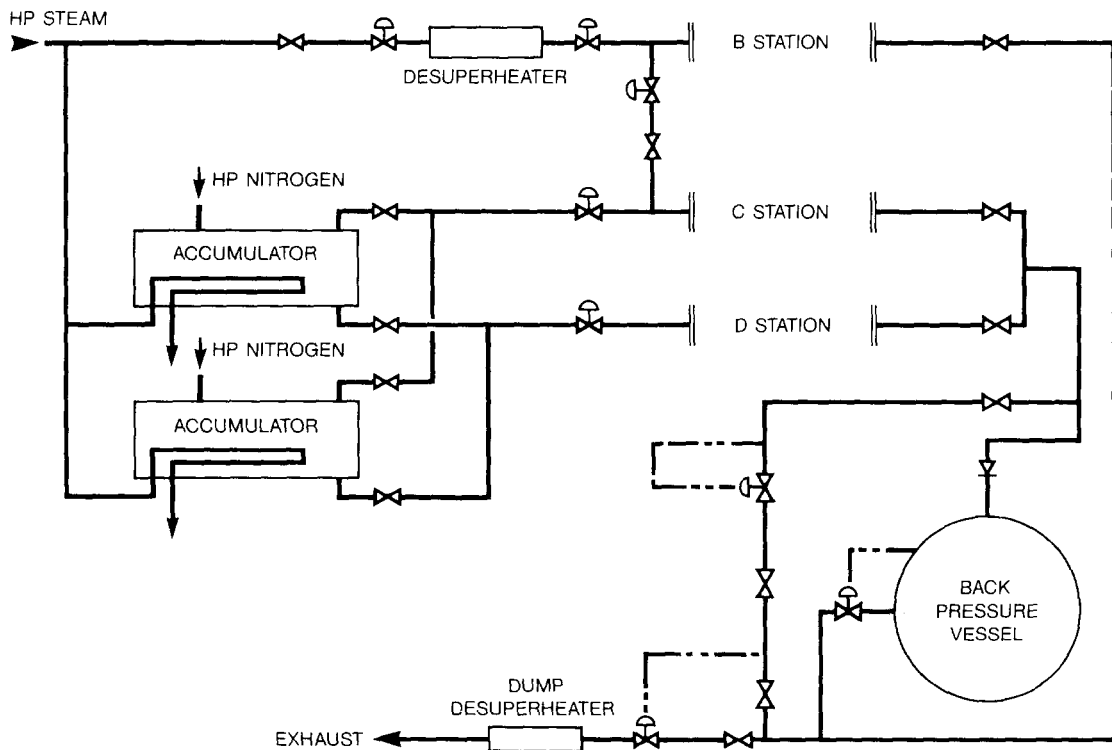


FIG. 1—THE SAFETY VALVE TEST FACILITY

When NAMD had been involved with naval steam raising plant for some 60 years nuclear power was selected for submarine propulsion. NAMD was an obvious choice for the testing of some nuclear steam plant components, largely because many of the facilities required already existed. A new machinery test house, of some 1500 m<sup>2</sup>, was constructed in the early 1960s with an adjacent boiler house containing two high pressure boilers. The boilers provided steam for trials facilities and use two large condensers (with cooling water from Haslar Creek) to recover the exhaust steam. The Relief and Safety Valve Test Facility (SVTF) (FIG. 1) is a major user of the steam provided.

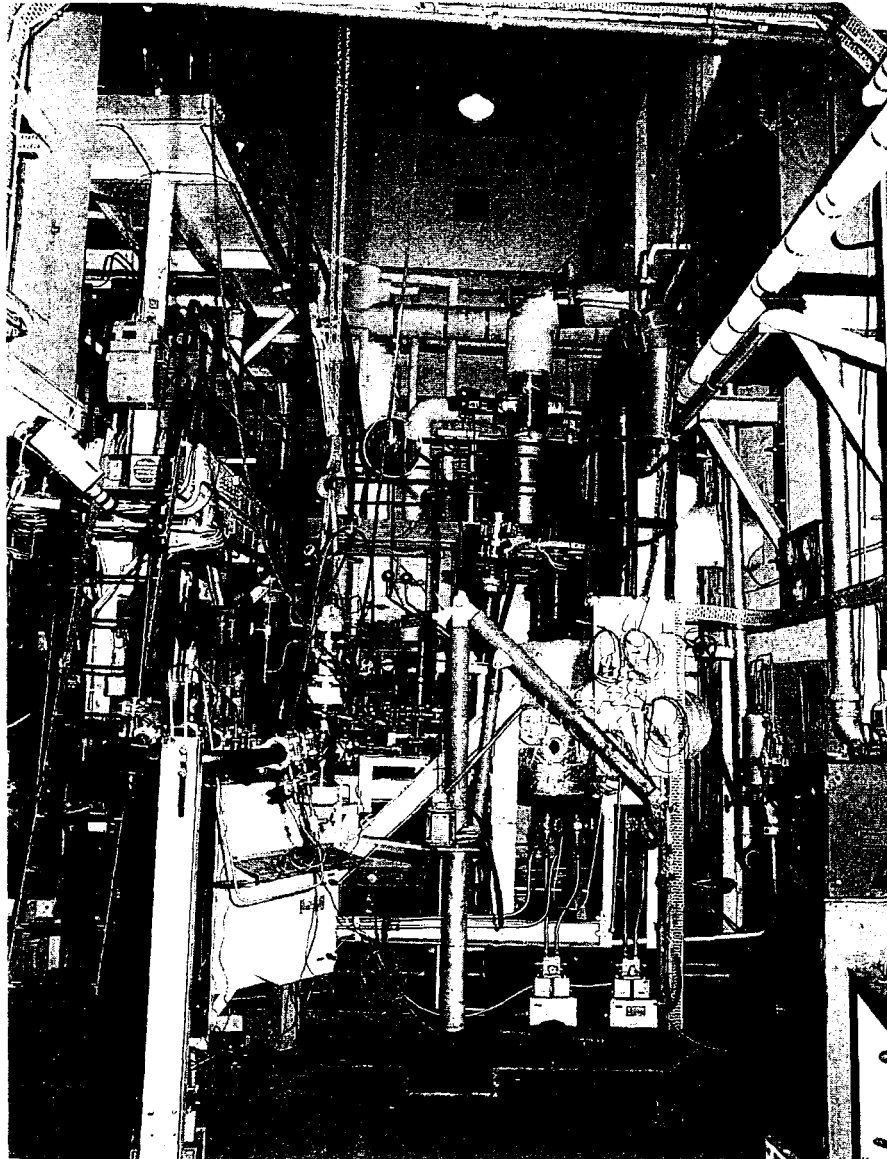


FIG. 2—THE RELIEF AND SAFETY VALVE TEST FACILITY AT HASLAR

### **The Relief and Safety Valve Test Facility**

The facility's function is the full flow testing of steam and water relief valves. It was designed to accept steam from the high pressure, high temperature boilers and use the existing condensing plant. Since being commissioned in the mid 1960s a large number of relief valves of many types have been tested for H.M. ships and submarines.

Sited close to the boilers, the facility (FIG. 2) can be supplied with steam at 82.5 bar (1200 lb/in<sup>2</sup>) and 510°C (950°F). The boiler steam conditions are insufficient to cater for all test requirements, and the necessary conditions are achieved using three test stations and accumulators, where demineralized water is heated using boiler steam. After passing through the test loops steam is desuperheated and dumped into the exhaust main.

Two of the three test stations are available for testing steam relief and safety valves and one for testing water valves. Operating conditions are shown in TABLE I. A fourth, low pressure, station was removed several years ago as it was no longer required. The supply systems upstream of each station can be isolated, but downstream they are grouped, which means that only one station may be used at a time.

TABLE I—Operating conditions in the test stations

Test Station	Supply	Supply Pressure		Maximum Temperature °C	Flow Rate	
		maximum bar (psi)	minimum bar (psi)		maximum kg/s (lb/s)	minimum kg/s (lb/s)
B	Steam	80 (1160)	40 (580)	510	11.4 (25)	1.9 (4.1)
C	Steam	207 (3000)	138 (2999)	379	4.4 (9.7)	0.4 (1)
D	Water	207 (3000)	138 (2000)	340	31.6 (69)	3.2 (7)

The object of testing is to simulate the conditions that valves experience in service and to assess their suitability for operation, proposing any necessary modifications to ensure this. When conditions upstream have been stabilized, tests can be initiated by the operation of fast operating solenoid valves from a console in the control room. Fast response instrumentation, connected to a data logging system, is provided for continuous recording of test parameters, including inlet and outlet pressures, inlet temperature and the flow rate for the duration of the test.

For B station, steam is supplied direct from the boilers, the pressure being controlled or reduced to the desired value. Steam temperature is controlled by use of a desuperheater fitted upstream. The exhaust is discharged to the condensers via a spray type dump desuperheater.

For C station, high pressure steam is generated in two accumulators, (FIG. 3), filled with hot water. Each is fitted with an integral steam coil through which boiler steam is circulated until the accumulator's steam conditions are raised to the required values. The exhaust is led to the condensers via the dump desuperheater. Provision is made in the exhaust system for the imposition of a back pressure on the valve under test. Exhaust is led to the back pressure vessel which can be supplied with steam or air to raise the internal pressure. The outflow is governed by a control valve which can be set to operate at the required back pressure.

A cross-over line is provided between B and C stations so that low pressure steam valves in the former can be tested against the back-pressure facilities of C station.

In D station, for water pressure tests, the accumulators can be filled with either hot or cold water. The temperature and pressure can be raised as necessary, using heating coils. The test pressure is applied using high pressure nitrogen from a bank of storage cylinders. Exhaust and back pressure facilities are the same as those available in C station. For hot water tests the back pressure is generated by using steam on the back pressure vessel. For cold water tests air is used for this purpose.

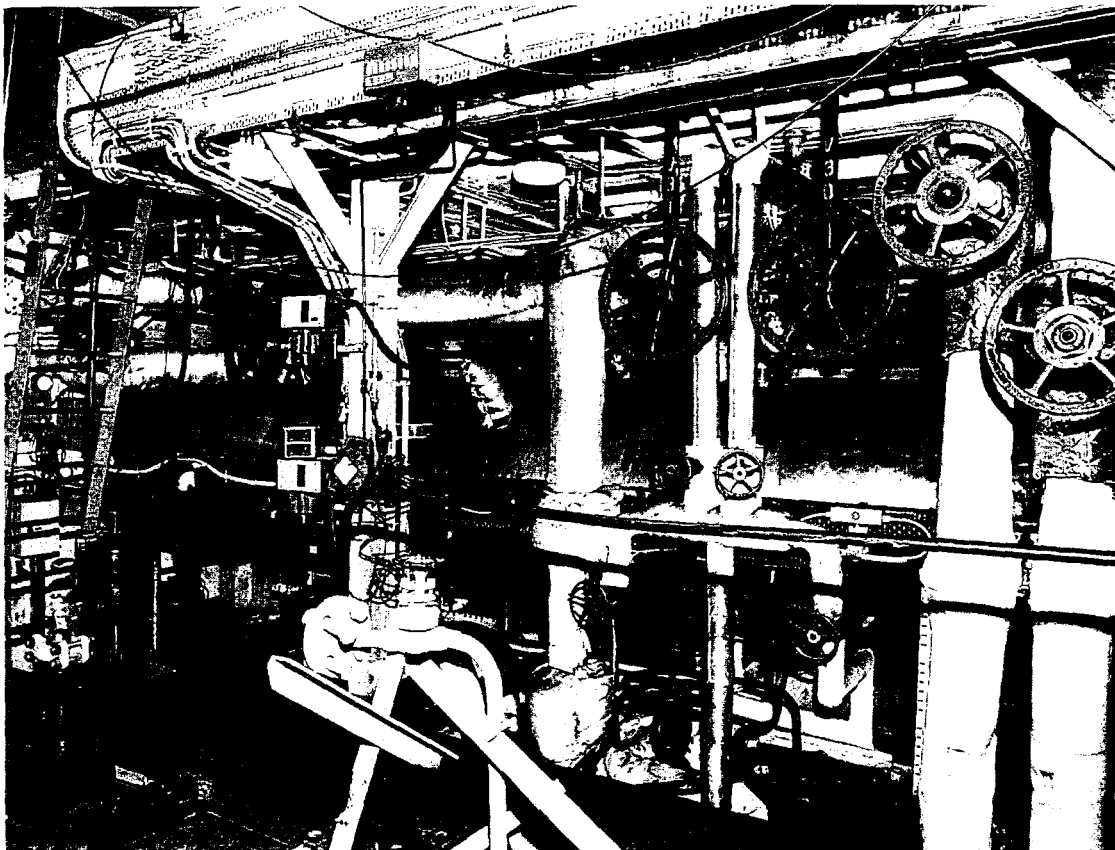


FIG. 3—ACCUMULATOR

The nitrogen pressurizing system consists of a bank of high-pressure storage cylinders, together with discharge control valves, a nitrogen pre-cooler and low and high pressure compressors. The compressors operate in series to pump up the storage cylinders to 276 bar (4000 lb/in<sup>2</sup>) from a bulk storage of liquified nitrogen. The high pressure compressor is used to reclaim nitrogen from the accumulator via the pre-cooler. The low pressure compressor can be used to supply air to the back pressure vessel as required.

Low and high pressure water pumps are fitted to supply spray water to the dump desuperheater and the B station desuperheater respectively. A feed water transfer pump is provided to transfer feed water from the feed tank to the accumulators or back pressure vessel as required. Feed water of high quality and low oxygen content can be supplied to the ready use tank from either the boiler feed system deaerator extraction pump discharge or an automatic two-bed deionizer with oxygen removal cylinders. A feed water pre-cooler and feed water heater are provided for use in the system as required.

### Valve Testing

The valve under test is mounted in a test loop between the inlet and exhaust flanges on the appropriate station (FIG. 4). The inlet flange is at a lower level than the exhaust flange—approximately 2 m above and to one side. The test loops inserted into the stations generally consist of 50 mm nominal bore stainless steel pipe. Incorporated into these loops are filters, strainers, stop and throttle valves in addition to the pressure transducers, thermocouples and flow meters required for data acquisition. Extensive use is made of fittings with 'Grayloc' couplings which allow quick and easy changes to the loop configuration; without these much time would be required to change loops—indeed it is possible that special welded loops would be required for each trial. All instruments are connected to a remote control room (FIG. 5) and the computer-based data capture and analysis system.

### Test Sequence—Water

Feed water is cooled, passed through the demineralizer and then pumped via the feed heater to the accumulators. The feed enters them at approximately 205°C (400°F) and superheated steam at conditions up to 510°C (950°F), and 82.5 bar (1200 lb/ins<sup>2</sup>) is then admitted to the accumulator heating elements. The water temperature is raised at a maximum of 56°C (100°F) per hour until required test temperature is reached. This restriction is required to prevent thermal shock and potential long-term damage to the pressure vessels.

For the test, water is introduced to the test rig through a series of valves. The pressure in the system is allowed to increase slowly but it must be maintained below the set pressure of the valve under test. Pressure increase

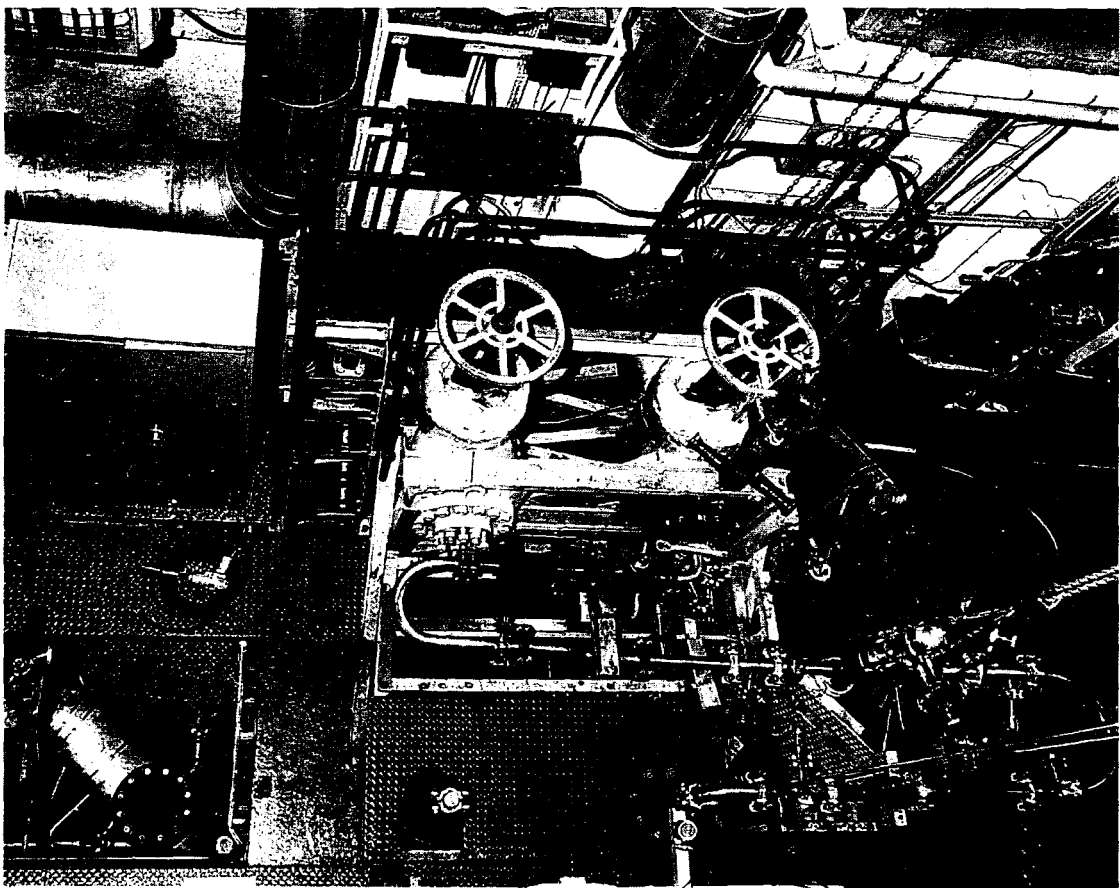


FIG. 4—VALVE TEST LOOP. B, C AND D TEST STATION INLETS ARE AT THE BOTTOM OF THE PICTURE; C AND D EXHAUSTS ARE IN THE MIDDLE. A VALVE IS CONNECTED FOR TEST IN D STATION

to the lift pressure is achieved by the admittance of nitrogen, at a controlled rate, into the accumulator. The valve under test will lift; pressure and flow are then maintained for a period (normally specified for the valve) by continuing to admit nitrogen. When it is required to shut the valve, nitrogen is shut off and pressure decays allowing the valve under test to shut. In order to achieve a reasonable sample of data this operation is repeated as required. If required by the test specification this operation can be repeated against a back pressure. Some two or three hours are required to allow the rig to cool sufficiently to allow nitrogen recovery.

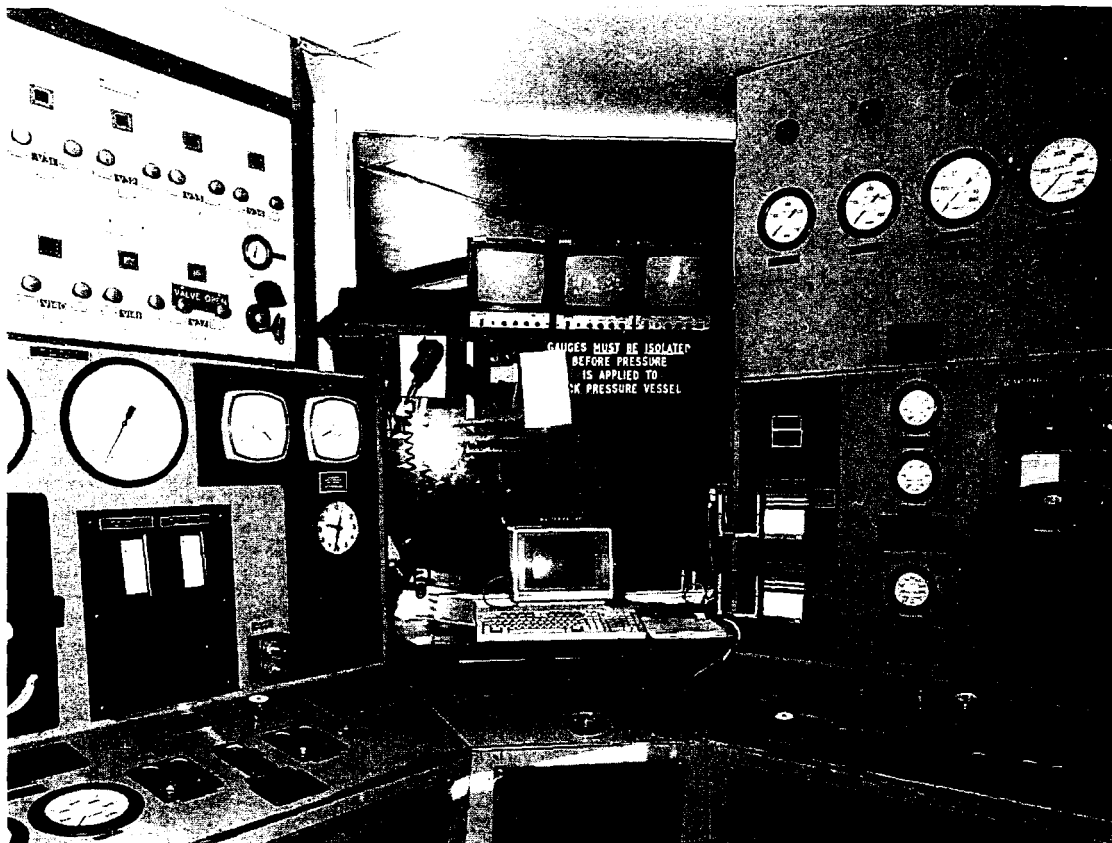


FIG. 5—SVTF CONTROL ROOM

### *Test Sequence—Steam*

The sequence is similar to that for the test under water pressure but with variation of pressure and temperature. Water is admitted to the accumulators, which will have cooled during nitrogen recovery, and then brought to the required conditions by admitting superheated steam to the heating elements. The time taken will depend on the accumulator temperature—say three to four hours if warm, and longer if cold.

The test is conducted by admitting steam to the test rig through a series of isolating valves. Again, care must be taken to ensure that rig pressure remains below the lift pressure of the valve under test. The flow of superheated steam to the accumulator is increased until the lift conditions are obtained. Steam flow is maintained for approximately 30 seconds after lift; then pressure decays and the valve shuts. The accumulator pressure is then allowed to rise for the next test lift. The process is repeated until the required number of lifts have been completed or until the steam/water in the accumulator is exhausted. As with water tests further testing against a back pressure can be conducted. To cover a full range of test lifts will take between 1 and 2 hours.

On completion of hot testing, further cold testing is normally carried out to check if the temperatures have affected the valve characteristics—seat leakage, spring turn to lift pressure relationship, etc. If necessary this can be carried out on the hot rig after cooling.

### *Instrumentation*

Generally the instrumentation used for all tests is similar. Variations in type or range of pressure transducers, thermocouples, etc., are made to suit the specified performance of the valve under test. When the test rig has been assembled, the instrumentation is calibrated with respect to the data capture system using a source input at the point of measurement. Other rig measuring equipment, e.g. flow meters, is removed periodically for re-calibration within NAMD or by manufacturers.

All calibrations must, naturally, be traceable to a nationally recognized standard.

### **Data Acquisition and Records**

For effective assessment of a valve under test, reliable, precise and accurate instrumentation is essential. A large volume of data may be generated and a quick and simple means of appraising this is required. When first commissioned the SVTF used a recording system based upon ultraviolet trace recording. Two UV recorders, each capable of recording up to 12 parameters were installed. These proved satisfactory for many years, being reliable and easily read. However the precision and accuracy is dependent upon the thickness of the trace and what was possible and acceptable 20 or 25 years ago can now be improved upon. Similarly the UV trace was very suitable for a quick appraisal, but detailed analysis was a time-consuming and difficult task. Inspecting lengthy traces, taking measurements and applying a variety of mathematical corrections and conversion factors did not lend itself to speed or accuracy.

Today a replacement recording system is in operation. Installed in early 1986, this computer-based data logging and analysis system provides both speed and precision. The original specification for this data logger required it to:

- (a) Replace the UV chart method of data recording with a more flexible and accurate method.
- (b) Provide an enhanced equivalent to the UV system in terms of graphical display/hard copy facilities including an inbuilt measurement capability and high quality presentation of analysis results.

The data logging system installed meets the requirements in the following ways:

- (a) Typical valve tests do not last for more than three minutes, although preparation may take several hours. To monitor the sensors, transducers, flow meters and thermocouples the system scans the inputs in three different groups, governed by the rate of scan. These groups are known as slow (10 Hz), medium (100 Hz) and fast (variable 0–5 kHz). The sensors are hardwired into the system to 'Klippon' type connectors. Each sensor provides signals to one logging channel, 64 of which are available.
- (b) The operator selects the scan rate for each logging channel and the system collects data and stores it onto a file on a hard disc. Since different valves are tested on the rig the operator chooses which channels are required for any particular test and ensures that they have been calibrated as required.

- (c) Data is stored on the disc in a raw form. Conversion to selected engineering units is restricted to those required for display during logging. The raw data file is converted to engineering units before analysis. This is accomplished using either polynomial expressions or multipliers entered by the operator (normally at calibration). As a routine raw data files are converted daily on completion of logging and stored on a magnetic tape. Thus changes in calibration necessitated by daily checks on instrumentation do not affect the data conversion process.
- (d) When viewed the data is presented as a line graph or series of line graphs of engineering units against time or, if required, any selected parameter logged. The operator is able to move a cursor in both axes and obtain more precise numerical indication of the value required. A facility for 'zooming in' to any area of the display is provided, and may be repeated for up to ten times—thus it is possible to display individual logging points if needed. Up to six selected channels may be displayed at any time. The displays may be plotted as hard copy suitable for direct incorporation into test reports.

### **Possible System Enhancement**

Before the SVTF can be operated, the two high pressure accumulators have to be heated to the operating conditions at a controlled rate, with the temperature rise limited to 56°C (100°F) per hour in order to minimize thermal stresses. At present this is done by passing superheated steam from the high pressure boilers through heating coils situated low in the accumulators. They are so designed that only the superheat from the steam can be used. No use is made of the latent heat which is simply dumped with the exhaust steam into the condensing plant. In the mid sixties this was a reasonable method of operation; however since then the cost of fuel has increased greatly and it is now an extremely wasteful and expensive method. However for the actual test when high rates of heat transfer are required such a method is still the most practicable.

A short study was carried out to investigate the feasibility of installing alternative means of heating the accumulators before the tests. The methods considered were:

- (a) Steam heating using a small boiler.
- (b) Electric heating.
- (c) Thermal fluid heating.

Any modification to the accumulator was ruled out on grounds of cost. Thus heating has to be either by direct steam injection or circulation of the accumulator water through an external heat exchanger. Steam injection was discounted as the accumulators could not be heated to temperatures near to those required unless very high pressures were used: additionally to maintain water standards sophisticated water treatment would be required to ensure that steam leaving the small boiler is of nuclear standard. Electric heating was also discarded because of the problems and hence cost of providing power supplies and a heater which would obtain the required conditions.

A more detailed study into the installation of a fired thermal fluid heater and heat exchanger was conducted and the proposal has been shown to be both feasible and practicable.

The maximum operating temperature of the heat transfer fluid is 330°C, so that conditions close to those required for test could be obtained. The high pressure boilers would still be required for the final stage of heating for many tests and also for the actual testing. Siting a heat exchanger



external to the accumulators removes any installation and maintenance problems. Connections to the accumulators are relatively simple since existing steam injection nozzle connections would be used. A circulating water system employing a high pressure/high temperature pump would be required. This would assist in providing uniform heating by circulating the water in the accumulators. The heat exchanger must be designed on the basis of forced convection heat transfer on both internal and external surfaces—this gives higher heat transfer coefficients and allows a relatively small U tube heat exchanger. During actual testing this heat exchanger would have to be isolated from the accumulators and would not experience sudden shocks or thermal stresses.

The proposed heating arrangements have been accepted as a sensible energy saving measure which will, as a bonus, allow more flexibility of operation of the test facility.

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